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# IMPACT OF FLOOD AND EROSION DAMAGE AND COSTS OF PROTECTION ON THE NORTHERN OHIO REGIONAL ECONOMY, 1972-1976

by

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# Impact of Flood and Erosion Damage and Cost of Protection on the Northern Ohio Regional Economy, 1972-1976

## Introduction

One hundred and ninety miles of Lake Erie's shoreline fall under the jurisdiction of Ohio. This area is particularly valuable to the state as a center of industry, commerce, agriculture, and recreation. It is also a densely populated region. However, much of the land is susceptible to periodic flood and erosion damages from the Lake associated with high winds and storms.

Few estimates of damage to shoreline property and the economic losses to private property owners due to flooding and erosion have been made. Some studies have focused on the potential costs of protecting the shoreline; others on measures to control and regulate Lake Erie water levels to avoid the high levels that increase the probability of damage in the event of a storm and the low levels that interfere with recreational and commercial interests. Some studies have dealt with the problem at the local level and are project-specific.

In the early 1970s, the lower Great Lakes were especially hard hit by storms that caused extensive property damage. In November 1972, in March 1973 and again in April 1974, several counties in northern Ohio were declared federal disaster areas due to the severity of the storm-related damage they sustained.

In 1976, the U.S. Army Corps of Engineers was charged with conducting an extensive survey of private property owners along the entire U.S. Great Lakes shoreline in order to assess the

extent and nature of damages occurring during that period and the expenditures made to protect their properties. In this study we utilize the damage and cost of protection estimates generated by the Corps study for the state of Ohio. Using an input-output model of the northern Ohio regional economy, an attempt is made to estimate the amount of resources within the region that went for the restoration, replacement and/or protection of private property instead of for production of the usual goods and services.

## Characteristics of Lake Erie and Its Shoreline

The state of Ohio includes over 190 miles or about 56 percent of the U.S. Lake Erie shoreline ($GLBC_b$, 1976). Generally the land bordering the western basin is low-lying and at one time contained extensive wetlands. Today, although much of the original marshland has been drained, some areas of northwestern Ohio remain flood-prone.

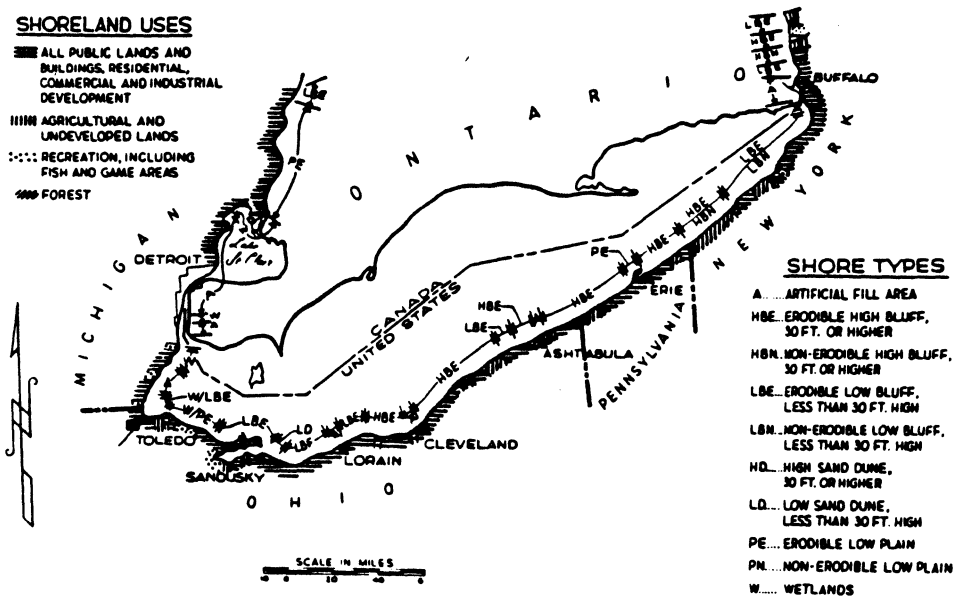
Approximately 79 percent of Ohio's Lake Erie coastline is classified as being susceptible to erosion (Table 1). As shown in Figure 1, erodible lands of the western basin are of the low bluff and low plain type whereas erodible high bluffs dominate the southeastern shore. Although erosion is an ongoing, natural process along Lake Erie, it is exacerbated during periods of high water and during storms.

Table 1. Classification of Ohio's Lake Erie Shoreline by Land Type

| Land Type | Miles | Percent |
|---|---|---|
| Erodible | | |
| Erodible High Bluff | 72.7 | 38 |
| Erodible Low Bluff | 55.1 | 29 |
| Erodible Low Plain | 19.9 | 10 |
| Wetlands/Erodible Plain | 3.5 | 2 |
| Total | 151.2 | 79 |
| Non-Erodible | | |
| Artifical Fill Areas | 15.1 | 8 |
| Low Sand Dune | 12.4 | 7 |
| Non-Erodible Low Bluff | 5.5 | 3 |
| Wetlands | 4.1 | 2 |
| Non-Erodible High Bluff | 2.0 | 1 |
| Total | 39.1 | 21 |
| Total | 190.3 | 100 |

Source: $GLBC_b$, 1976.

Figure 1. Characteristics of the Lake Erie Shoreline.




Source: $GLBC_b$, 1976.

Ohio's Lake Erie shoreline is highly developed and densely populated. In 1970, only 14 percent of the shoreline was undeveloped or devoted to agriculture. Another two percent was forest and woodland whereas over half was classified as residential ($GLBC_e$, 1976).

In that year, publically owned land made up nearly 20 percent of the total, including fairly large state and federal wildlife refuges and parks just east of Toledo and county and municipal recreational land elsewhere along the coast. Eight percent of the land was held by industrial firms; much of it concentrated in the east around Conneaut, Ashtabula, Painesville, Fairport Harbor, Cleveland and Lorain, and at the extreme western end of the state in Toledo.

Lake Erie is the shallowest of the Great Lakes with an average depth of only 62 feet. From the shallows at the western end where water depths average 25 to 30 feet, the Lake drops to a maximum depth of 212 feet in the east ($GLBC_a$, 1976).

Lake Erie is situated so that its long axis is oriented in a general southwest-northeast direction along the path of the prevailing southwest winds. It is characterized by lowlands at its western end and bluffs of over 30 feet in height along much of the length of its central and eastern basins. It is this unique combination of factors which makes Lake Erie especially susceptible to storm damage.

High winds accompanying low pressure systems originating from the northeast can push water to the western end of the Lake. Here it gradually builds up since subsurface flows are restricted

by the shallowness of the Lake. If such weather disturbances are of sufficient duration, water can inundate low-lying areas causing flood, erosion and wave damage to property and structures. Although the high bluff shoreline areas of the central basin are susceptible to erosion, during the period covered in this study, erosion-related damages tended to be concentrated in the western basin.

## Lake Erie Water Levels

Lake Erie water levels vary seasonally. Peak volumes are reached during the summer months and lows occur in the winter. Although a number of factors--freezing, snow and ice melt, evaporation, ground water flows and crustal movements--contribute to these seasonal variations, the most significant determining factor is precipitation which adds to the Lake's volume directly and also indirectly through the runoff carried by streams and rivers within the Lake's natural drainage basin.

With their large areas, the Great Lakes can usually handle short-term excesses of precipitation although the capacities of the rivers connecting and draining them are limited. Thus, if precipitation is abnormally high over time as during the period covered in this report, Lake levels may rise and remain significantly above their long-term averages for long periods of time. The potential for storm-related damage is greater under these conditions since deeper water allows waves to achieve greater heights and to break with greater force closer to the shore. In addition, high water levels change the effect of waves

on the shoreline in that natural beaches are submerged and waves can act directly on the more susceptible backshore, accelerating the normal erosion process.

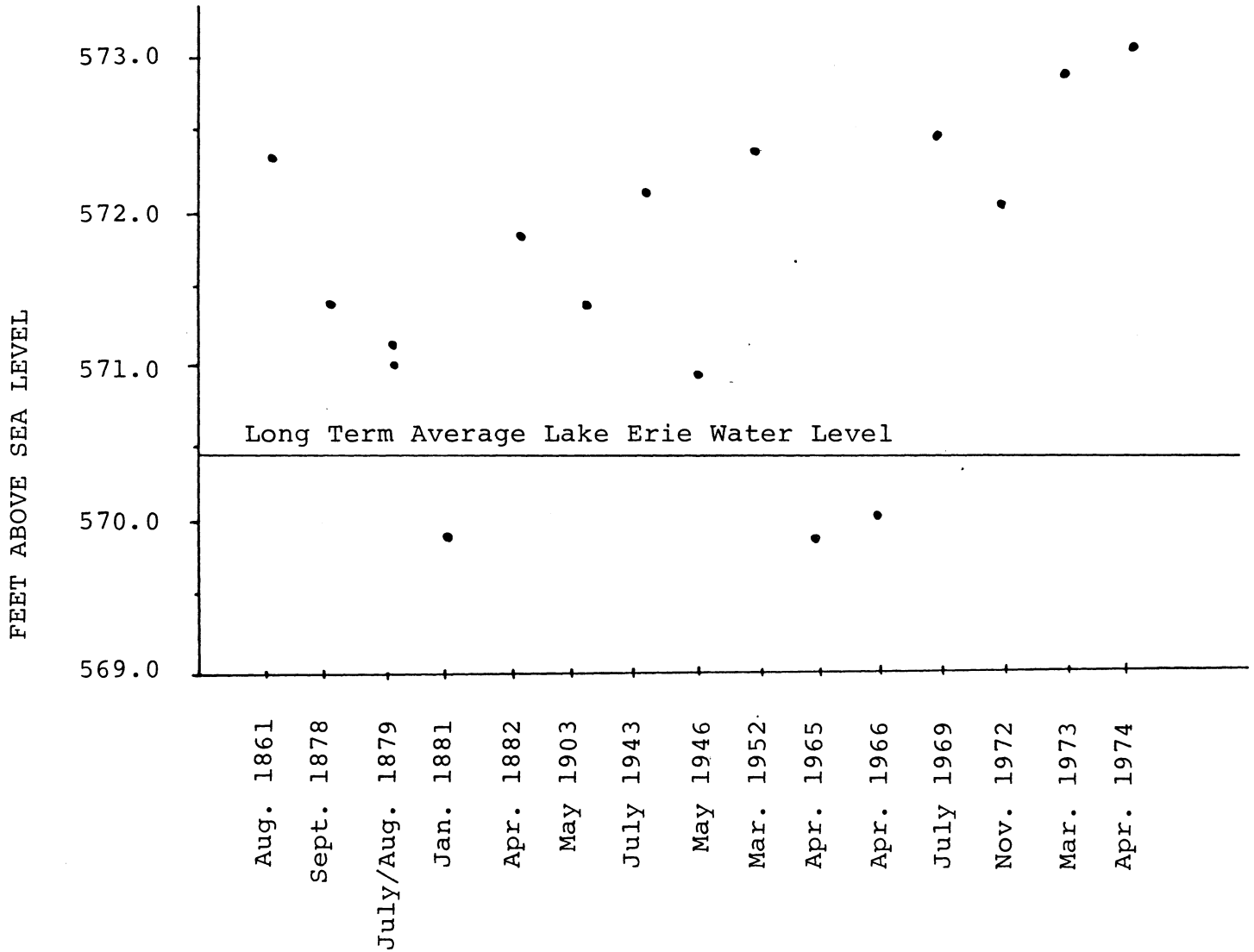
## The 1972-1974 Storm Events

Historically there have been a number of damaging northeast storms on Lake Erie, most of which occurred when water levels were high (Figure 2). Data in Figure 3 indicate that prior to and during the study period (September 1972 to September 1976), average annual precipitation over the entire Great Lakes basin and within the Lake Erie basin itself was greater than the long-term average. It was the severity, destructiveness and close spacing of the storms that made the early to mid 1970s a unique period for Lake Erie's shore communities.

### The Storm of November 13 and 14, 1972

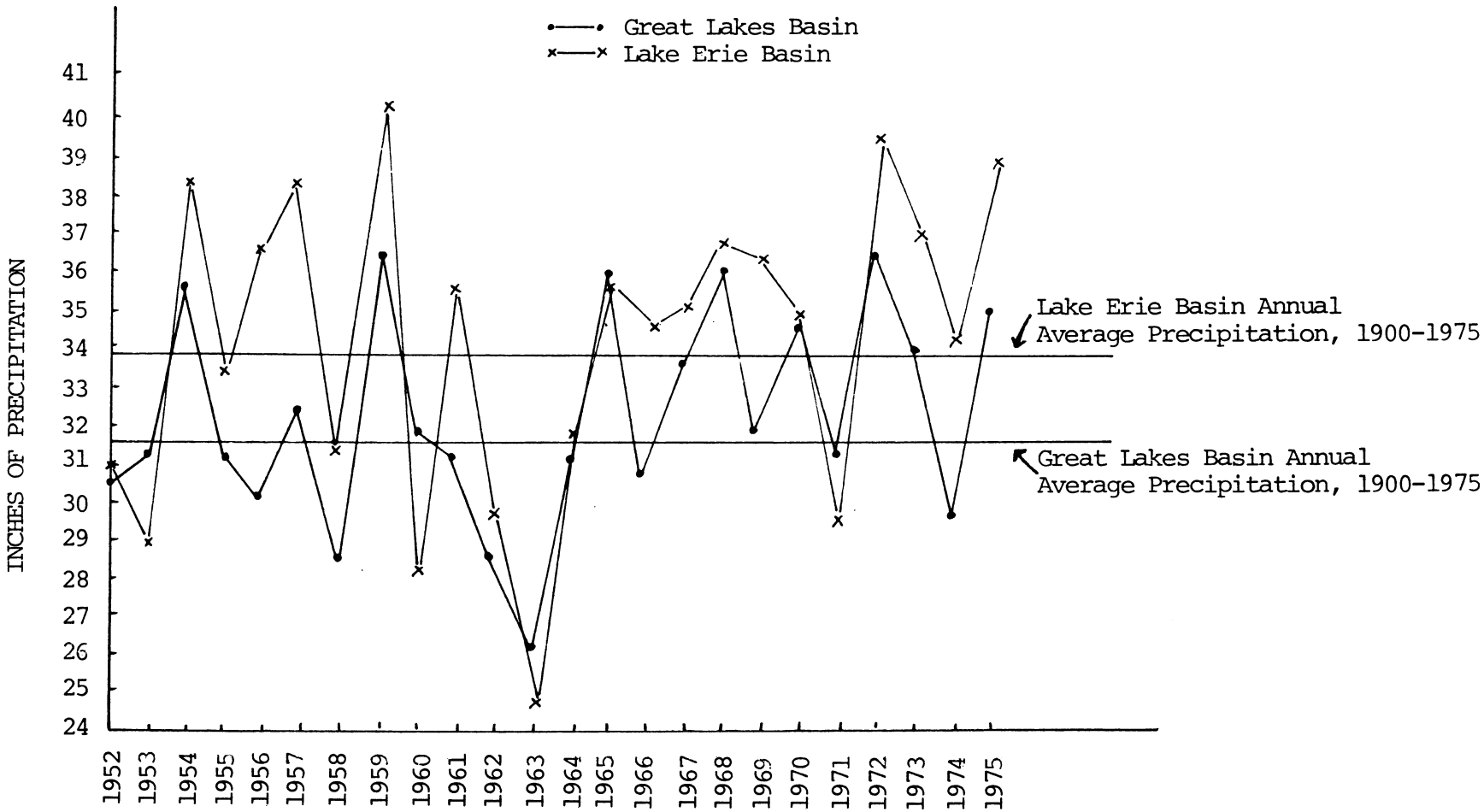
The storm of November 13 and 14, 1972 is considered one of the worst natural disasters in Ohio's history (Carter, 1973). It occurred when Lake Erie was about two feet above its long-term November average. A northeast wind began early on November 13 and continued until late on the 15th, eventually reaching speeds up to 45 miles per hour (Carter, 1973). The strong winds forced water to pile up against and then inundate extensive areas of the southwest shore. At one point, water levels reached a height at Toledo of more than six feet above the long-term November average, and waves of up to 12 feet were generated (Carter, 1973).

Figure 2. Average Monthly Lake Erie Water Levels During the Months in Which Severe Northeast Storms Occurred.




Source: Carter, 1973, pg. 4.

Figure 3. Annual Precipitation Within the Lake Erie and Great Lakes Basins, 1952-1975.




Source: U.S. Army-Detroit, 1977.

Residents from Huron, Ohio to Monroe, Michigan were forced to evacuate their homes because of flooding and waves. Many homes, roads and protective structures such as seawalls, dikes, beaches and dunes were damaged or destroyed. Flooding occurred where waves breached dikes and other protective structures surrounding low-lying areas. Because some of the land in northwest Ohio contains high levels of clay, floodwater could not readily percolate downward, and in some places, the ground was covered with water for several days.

Following the storm, seven Ohio counties (Lucas, Ottawa, Erie, Sandusky, Lorain, Cuyahoga and Lake) and nine Michigan counties were declared a major disaster area by the Small Business Administration. This made flood victims eligible for low-interest loans to restore and/or replace damaged or lost property and structures. Eventually northern Ohio was declared a major disaster area by President Nixon which made federal funds available for direct relief and for the repair and restoration of public facilities.

In making his request for federal aid, Ohio's Governor Gilligan estimated that more than $22 million of damage had been sustained in Ohio (Toledo Blade, November 24, 1972). A preliminary survey showed damages of $12 million to 2000 homes and $500 thousand to 24 businesses in Lucas, Ottawa and Sandusky counties alone (Toledo Blade, November 18, 1972). Eventually as a result of this storm, certain Ohio cities and townships within

the disaster counties and the Ohio Departments of Natural Resources and of Transportation were granted a total of $615,862 of direct federal aid (Deborah Patchen, 1984).

Operation Foresight

The Detroit District, U.S. Army Corps of Engineers publishes monthly estimates of anticipated water levels for the Great Lakes which are then extended for the next six months. During the second half of 1972 when above-average levels of precipitation fell within the Great Lakes drainage basin, forecasters predicted that the spring, 1973 water levels would approach or exceed the last extreme high of 1952 and possibly cause severe flooding around the Great Lakes except Lake Superior. In view of these predictions, Operation Foresight was activated and authorized on December 15, 1972. Ohio's governor responded to the announcement on January 30, 1973.

Operation Foresight, a program initiated under the provisions of PL84-99, authorized the U.S. Army Corps of Engineers to conduct studies to determine sites along the Great Lakes shoreline where temporary flood emergency operations would be practical (erosion control was not specifically provided for under Operation Foresight). Among the criteria set out in the law were that flood protection measures must exceed the capabilities of state or local resources, be justified from an economic and engineering standpoint, be of a temporary nature, be designed to handle the anticipated high water levels and be completed in time to be of use. As outlined in the laws, maintenance and

removal of protective structures were local responsibilities. In some cases where a project was not approved, materials were offered on a self-help basis to communities that agreed to supply voluntary labor.

Fifty-nine communities in seven states received $26.8 million of assistance through Operation Foresight (Table 2). Eighty-four percent ($22.3 million) went for contract projects and the rest was spent on self-help materials, mainly sandbags. Among the protective structures built under contract were earthdikes, riprap, sand and rock-filled cribs and stone-filled gabions.[1] The target date for completion of the projects was fall 1973 to early spring 1974.

Eight of the communities that received contract assistance were in Ohio.[2] Altogether they received $8.6 million or 40 percent of the total contract project award made to the seven states. Ohio's share of the self-help funds amounted to $175 thousand or four percent of the self-help total. Overall, the state of Ohio received nearly $8.8 million of Operation Foresight funds: 33 percent of the total allocated to the seven states.

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1 Gabions are offshore breakwaters designed to protect beaches. Riprap consists of a layer, facing or protective mound of stones randomly placed to prevent erosion. Cribs are large crate-like structures built against slopes and filled with rock or sand to lend support and protect the slopes from erosion (U.S. Army-NCD, 1978, U.S. Army-LCSP, 1978).

2 The eight project sites were Point Place in Toledo, Reno Beach/Howard Farms, Bay Township, Whites Landing, Bayview, Eastlake, Conneaut Water Intake and Crystal Rock. Forty-five other sites in Ohio were considered and then rejected because they failed to meet one or more of the Operation Foresight guidelines.

Table 2. Operation Foresight Costs and Estimates of Damage Prevented to the Great Lakes Shoreline, 1973-1974.

| | Costs[1] | Estimated Damages Prevented |
|---|---|---|
| | $ million (percent) | |
| Contract Projects[2] | | |
| Ohio | 8.621 (39) | 22.126 (18) |
| Other States[3] | 14.192 (61) | 97.859 (82) |
| Total | 22.318 (100) | 119.985 (100) |
| Self-Help Projects | | |
| Ohio | .175 (4) | .477 (6) |
| Other States[3] | 4.257 (96) | 11.800 (94) |
| Total | 4.432 (100) | 12.277 (100) |
| Total | | |
| Ohio | 8.796 (33) | 22.603 (17) |
| Other States[3] | 18.017 (67) | 109.659 (83) |
| Total | 26.813 (100) | 132.262 (100) |

[1]Includes materials and administration costs.

[2]Contracts were awarded to local firms by the U.S. Army Corps of Engineers.

[3]Other states included Wisconsin, Illinois, Indiana, Michigan, New York and Pennsylvania.

Source: U.S. Army-Detroit, 1977.

The March, 1973 and April, 1974 Storms

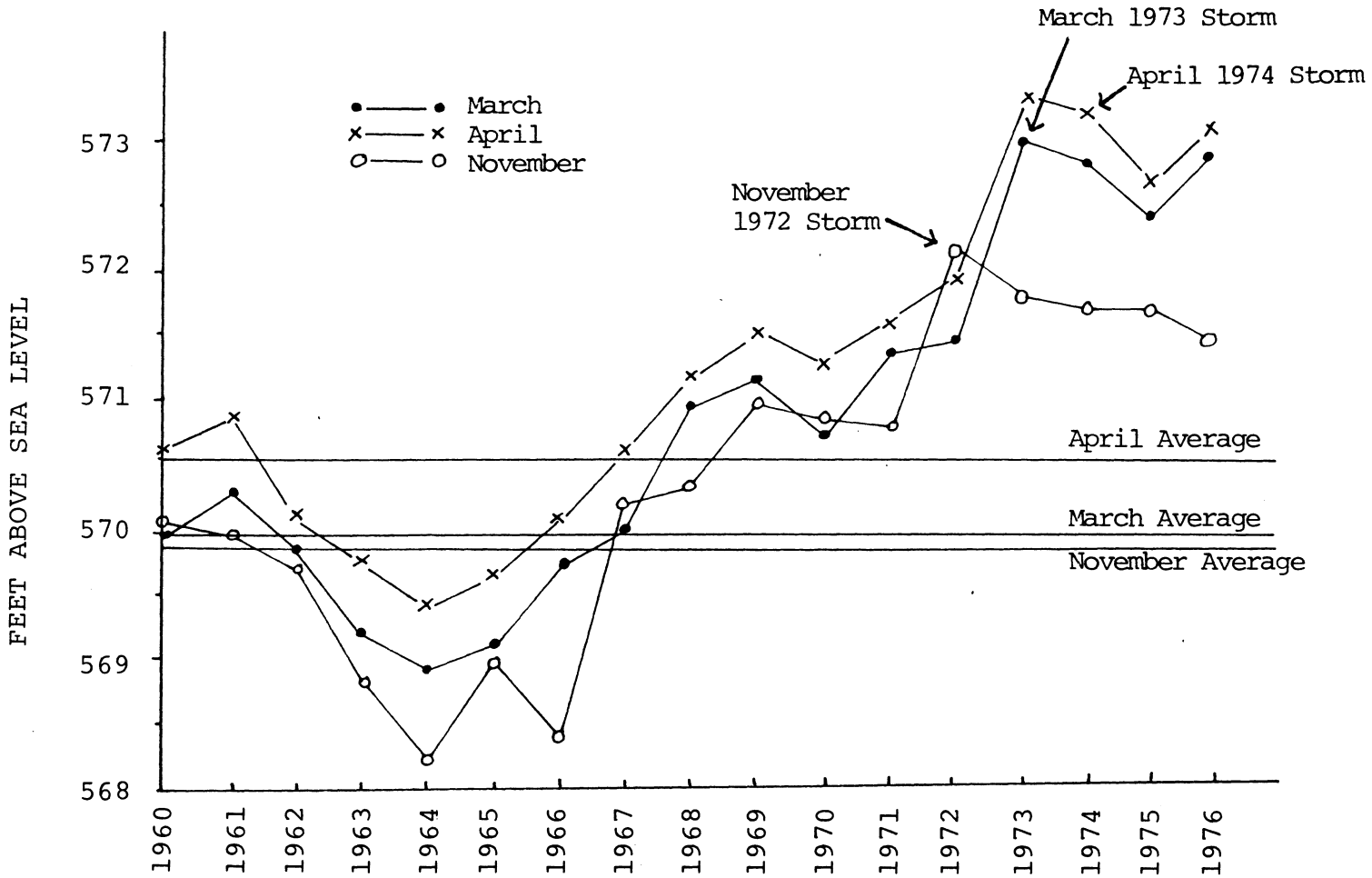
Much less detail is available on the other two major storms. However, a similar sequence of events occurred in March, 1973 as with the November, 1972 storm. The April, 1974 storm was associated with a weather disturbance that caused the Xenia tornado.

In the aftermath of the March, 1973 storm, eight northern Ohio counties were declared a major disaster area by the President and by the Small Business Administration. After the April, 1974 storm, three Ohio counties (Lucas, Ottawa and Sandusky) were designated as a disaster area. Flooding associated with both of these storms was worse than that which occurred in 1972 because of higher water levels (Figure 4).

In 1973, $1.418 million in federal aid went to cities, villages and townships within the eight county disaster area as well as to the Ohio Department of Natural Resources and to Camp Perry, a National Guard installation (Deborah Patchen, 1984). In 1974, certain cities, towns, villages and conservancy districts within the three county disaster area and the Ohio Departments of Natural Resources and of Transportation received federal grants totaling $859 thousand (Deborah Patchen, 1984).

The eight Ohio Operation Foresight contract projects were completed between April and November 1973 so they were not in place until after two of the three major storms of the study period. The U.S. Army Corps of Engineers estimated that in Ohio, Operation Foresight projects prevented more than $22.6 million of

Figure 4. Average Monthly Lake Erie Water Levels: March, April and November, 1960-1975.




Source: USDC-NOAA, No date, pg. 47.

damage through 1974.[3] The Corps of Engineers inspected the eight contract project sites in 1976 and found them all functional. The 1976 status report referred to additional flooding in the fall and winter of 1973, March 1974 and the spring of 1975. A newspaper account mentioned that three windstorms in 1973 were associated with some shoreline flooding (Sandusky Register, 1974). To what extent damages at Operation Foresight sites were lessened by the presence of protective structures is unknown.

## Damage Estimation

As a result of the unusual amount of damage sustained by the lower Great Lakes states in the early 1970s, the U.S. Army Corps of Engineers funded studies to assess the extent of damage to private property along the Lakes from Labor Day 1972 to Labor Day 1976. (The Corps of Engineers report cited here did not contain estimates of damages to public property.) In this study we use the results for the state of Ohio within the analytical framework of an input-output model for northern Ohio to estimate the total economic damages from these storm events between 1972 and 1976.

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[3] Field crews visited each site to determine at what water levels zero, intermediate and maximum amounts of flooding would occur. Using average property and structure value assessments for the area and applying water level projections that were termed "most probable," the Corps of Engineers derived their estimates of damages prevented. Because of time constraints, their calculations were necessarily rough.

Data from the Corps of Engineers Study

The study area for Ohio was defined as the 100-year open coast flood level and included properties both inland and along the Lake in eight northern Ohio counties: Lucas, Ottawa, Sandusky, Erie, Lorain, Cuyahoga, Lake and Ashtabula. The study area was then divided into subreaches based upon the susceptibility of the land to erosion and/or flood damage, certain demographic characteristics and proximity to the shore.

Field teams were sent to the eight county seats and information about each property was collected. Mailing lists were generated according to land use. The land use categories were: residential, commercial, industrial, transportation, utilities and agriculture/forestry (Data on public property were not collected for this report). Due to the large number of residential properties, a sample based on assessed property values was selected statistically and through linear extrapolation the sample results were later expanded to reflect the total population. All property owners in other land-use categories were sent questionnaires and the survey results were linearly extrapolated to account for non-responses.

Lake Erie's commercial sector at the time of the study was made up of diverse firms. Nearly 60 percent of the commercial firms were identified by private names only and could not be categorized. Of the commercial firms which could be categorized 30 percent were marina/boat sales operations, 12 percent were recreation-oriented such as sports clubs and camps, 9 percent were categorized as retail and 8 percent each were associated

with real estate or chemicals. Other commercial properties along Lake Erie were components of sectors such as finance, construction, electricity, eating/drinking establishments, wholesale, water transportation, commercial fishing, communications and machinery.

Thirty-nine land parcels were owned by industrial firms from the following sectors: paper and allied products, stone, clay and glass, chemicals and primary non-ferrous metals. In the Corps of Engineers study, commercial and industrial firms were grouped together.

Firms in the transportation category were railroads and a docking company, and several different power companies operating along the shoreline were classed as utilities. Residences and agricultural/forest land were owned by individuals and there were no data to enable any characterization of these properties.

## Estimates of Damage and Protection Costs

Corps of Engineers questionnaires were designed to collect detailed information from survey respondents on the amount and type of erosion and flood damage done to private property during the four year study period. Data were also collected on the costs incurred by property owners for shore and property protection. However, it was beyond the scope of this study to review individual questionnaires. Instead, sample surveys for each land-use category were examined and from information in the directions and throughout the questionnaires, a general idea about the nature of damages and protection was gained.

Damage

The distribution of flood and erosion damages by county is summarized in Table 3. Flood damages were concentrated in the western basin counties, especially Lucas and Ottawa which together accounted for 81 percent of the total. Central basin counties, in contrast, sustained only four percent of the flood damages. Western basin counties suffered nearly two thirds of the erosion damages over the study period. Among the hardest hit counties were Erie with 36 percent of the total and Ottawa with 26 percent. Damages to the four central basin counties were nearly equal.

Table 4 summarizes the extent of flooding and erosion damage to private property by sector during the period 1972 to 1976. Overall, flooding and erosion damages were nearly equal; both were over $32 million. An examination of Table 4 reveals that residential property owners suffered the greatest losses of the five sectors: 92 percent of the flood damages and 90 percent of the erosion damages. Commercial/industrial property owners sustained three percent of the flood and nine percent of the erosion damages whereas owners of agricultural/forest lands accounted for five percent of flood-related damages and less than one percent of erosion damages. Utility and transportation properties were virtually untouched by floods and each sustained less than one percent of the erosion damages.

Table 5 lists for each sector and for each damage category examples taken from the respective sample questionnaires to illustrate the types of property damage occurring over the study

Table 3. Percentage Distribution of Flood and Erosion Damage to the Study Region by County, 1972-1976.

| | Damage | |
|---|---|---|
| | Flood | Erosion |
| | (percent) | |
| Western Basin | | |
| Lucas | 32 | 2 |
| Ottawa | 49 | 26 |
| Sandusky | 2 | 1 |
| Erie | 13 | 36 |
| Subtotal | 96 | 65 |
| Central Basin | | |
| Lorain | <1 | 6 |
| Cuyahoga | 2 | 11 |
| Lake | 1 | 8 |
| Ashtabula | <1 | 10 |
| Subtotal | 4 | 35 |

Source: Bedford, et al. 1978.

Table 4. Flood and Erosion Damages to the Study Region by Sector, 1972-1976.

| | Structure and Contents | Grounds and Improvements | Clean Up | Emergency Evacuation | Financial Loss | Other Damages | Total Damage |
|---|---|---|---|---|---|---|---|
| FLOOD | ($M) | ($M) | ($M) | ($M) | ($M) | ($M) | (Percent) |
| Residential | 14.276 | 7.107 | 1.198 | 0 | 2.756 | 4.235 | 29.572 (92) |
| Commercial/Industrial | .263 | .413 | .121 | .011 | .199 | .026 | 1.033 (3) |
| Transportation | 0 | 0 | 0 | 0 | 0 | 0 | 0 (0) |
| Utilities | 0 | 0 | 0 | 0 | 0 | 0 | 0 (0) |
| Agriculture/Forestry | 0 | 0 | 0 | 0 | 0 | 1.613 | 1.613 (5) |
| Total | 14.539 | 7.520 | 1.319 | .011 | 2.955 | 5,874 | 32.218 (100) |
| EROSION | | | | | | | |
| Residential | 5.578 | 13.177 | 1.357 | 0 | 1.861 | 7.180 | 29.153 (90) |
| Commercial/Industrial | .881 | 1.492 | 0 | 0 | .013 | .724 | 3.110 (9) |
| Transportation | 0 | 0 | 0 | 0 | 0 | .036 | .036 (<1) |
| Utilities | 0 | 0 | 0 | 0 | 0 | .008 | .008 (<1) |
| Agriculture/Forestry | 0 | 0 | 0 | 0 | 0 | .084 | .084 (<1) |
| Total | 6.459 | 14.669 | 1.357 | 0 | 1.874 | 8.032 | 32.391 (100) |

Source: Bedford, et al. 1978.

Table 5. Flood and Erosion Damages by Sector and by Type and Percent of Total Damages Sustained by Private Property Owners, 1972-1976.[1]

| Sector | Structures and Contents | Grounds and Improvements | Clean Up | Emergency Evacuation | Financial Loss | Other Damages |
|---|---|---|---|---|---|---|
| Residential | residential buildings contents, detatched garages, non-residential buildings | docks, ramps, boathouses, stairways, lawns, trees, landscaping, septic systems | clean up | -----[2] | loss of rental and business income | -----[2] |
| | 31% | 31% | 4% | | 7% | 18% |
| Commercial/ Industrial | foundations, walls, merchandise, equipment, records, contents, stock redecoration, painting | parking lots, walls signs, lawns, shrubs, docks, wharves, boat and beach houses | clean up | evacuation and reoccupation (moving goods, temporary leasing space) | loss of business income and employee wages | -----[2] |
| | 3% | 3% | <1% | <1% | 1% | 1% |
| Transportation | bluff repairs, repairs of rights of way, foundations, pavements, surfaces, equipment | -----[2] | -----[2] | -----[2] | loss of business and employee wages | temporary rerouting costs, increased operating costs |
| | | | | | | <1% |
| Utilities | machinery, furniture and fixtures, mains, lines, cables, meters | roads, storage areas | clean up of equipment, grounds and structures | -----[2] | loss of business income and employee wages | -----[2] |
| | | | | | | <1% |
| Agriculture/ Forestry | -----[2] | -----[2] | -----[2] | -----[2] | -----[2] | livestock, crops, farm equipment, fences |
| | | | | | | 3% |

[1] Percentages are based on total flood and erosion damages: $64.609 million. Percentages total ≈100 percent due to rounding.

[2] No information on the nature of these damages was provided on the questionnaire.

Source: Bedford, et al. 1978

period. From this table, sectors in northern Ohio which were directly and indirectly affected by Lake Erie storms may be determined.

As noted previously, the residential sector accounted for the majority of the $64.6 million of erosion and flood-related damages. Thirty-one percent of that total ($20 million) occurred in the residential "structures and contents" category which included residences and furnishings, detatched garages and other outbuildings on residential properties. Another 31 percent was spent on residential "grounds and improvements" such as docks, boat ramps, boathouses, stairways, septic systems and landscaping. The remaining expenditures made by the residential sector were for clean-up, loss of rental or business income and "other costs" which could not be characterized due to lack of data. Flood and erosion damages for all other sectors were minimal when compared to those of the residential sector.

Costs of Protection

The distribution of protection costs by county summarized in Table 6 reveals that 87 percent of flood protection expenditures were made by property owners in the western basin. Over 50 percent of flood protection costs were borne by property owners in Ottawa county. Erosion protection expenditures on the other hand were more evenly distributed between the western and central basins. Expenditures were minimal in Lucas and Sandusky counties but Erie and Ottawa counties together accounted for 44 percent of

Table 6. Percentage Distribution of Flood and Erosion Protection Costs for the Study Region, by County, 1972-1976.

| | Costs of Protection | |
|---|---|---|
| | Flood | Erosion |
| | (percent) | |
| Western Basin | | |
| Lucas | 17 | 1 |
| Ottawa | 53 | 18 |
| Sandusky | 7 | 1 |
| Erie | 10 | 26 |
| Total | 87 | 46 |
| Central Basin | | |
| Lorain | 3 | 17 |
| Cuyahoga | 6 | 13 |
| Lake | 3 | 11 |
| Ashtabula | 1 | 13 |
| Total | 13 | 54 |

Source: Bedford, et al. 1978.

the total. Property owners in the central basin spent 54 percent of the total cost of erosion protection. Those expenditures were spread fairly evenly among the four counties.

Cost of protection data, by sector, appear in Table 7. As expected, residential property owners spent the most: 76 percent of flood protection expenditures and 92 percent of outlays for erosion protection. Property owners of the agriculture/forestry sector accounted for 21 percent of the total spent on flood protection. Protection costs for all other sectors were less than five percent.

Seventy-five percent of total protection costs was spent by residents for protective structures like seawalls, revetments and groins (Table 8).[4] Another three percent was spent on materials and labor for relocation of residence and seven percent was categorized as "other costs." The only other significant expenditures occurred in the agriculture/forestry sector under the category "other costs." Eleven percent of the total was spent by private property owners in this sector for flood proofing, ground covers, fences, draining tiles and irrigation lines. Costs of protection were minimal in the other sectors.

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[4] Revetments and groins are stone or concrete shore protection structures. The former are designed to protect embankments from erosion and the latter are built perpendicular to the shore to retard beach erosion (U.S. Army-NCD, 1978, U.S. Army-LCSP, 1978).

Table 7. Flood and Erosion Protection Costs Within the Study Region by Sector, 1972-1976.

| Protective and Other | Relocations ($ Mil.) | Structures ($ Mil.) | Costs ($ Mil.) | Total Costs $ Mil. (percent) |
|---|---|---|---|---|
| Flood | | | | |
| Residential | 1.012 | 9.921 | 1.773 | 12.706 (76) |
| Commercial/Industrial | 0 | .115 | .400 | .515 (3) |
| Transportation | 0 | 0 | 0 | 0 (0) |
| Utilities | 0 | .002 | 0 | .002 (<1) |
| Agric./Forestry | 0 | 0 | 3.596 | 3.596 (21) |
| Total | 1.012 | 10.038 | 5.769 | 16.819 (100) |
| Erosion | | | | |
| Residential | .295 | 18.726 | .739 | 19.760 (92) |
| Commercial/Industrial | .013 | .589 | .227 | .829 (4) |
| Transportation | 0 | .075 | 0 | .075 (<1) |
| Utilities | .150 | .008 | 0 | .158 (1) |
| Agric./Forestry | 0 | 0 | .696 | .696 (3) |
| Total | .458 | 19.398 | 1.662 | 21.518 (100) |

Source: Bedford, et al. 1978.

Table 8. Cost of Protection by Sector and by Type and Percent of Protection Costs Spent by Category, 1972-1976.[1]

| Sector | Relocations | Protective Structure | Other Costs |
|---|---|---|---|
| Residential | relocation of home/ cottage (materials and labor) | revetments sea walls groins | ----[2] |
| | 3% | 75% | 7% |
| Commercial/ Industrial | relocation of facilities and roads | jetties, groins revetments, dikes, levees, seawalls, flood-proofing, costs of temporary shore-up of structures | ----[2] |
| | <1% | 2% | 2% |
| Transportation | relocation of RR lines, roads, and bridges | permanent protection to prevent damage to RR lines, roads, bridges | ----[2] |
| | | <1% | |
| Utilities | relocation of facilities | emergency and permanent protection | ----[2] |
| | <1% | <1% | |
| Agriculture/ Forestry | relocation of structures | ----[2] | flood-proofing, terracing, fences, irrigation, lines, drainage, tiles, planting of ground cover |
| | | | 11% |

[1]Percentages are based on total flood and erosion protection expenditures: $38.337 million.

[2]No information on the nature of these damages was provided on the questionnaire.

Source: Bedford, et al. 1978.

## The Input-Output Model

A change in one sector of an economy leads to changes in its other sectors. To measure the total impact of a change in one economic activity on the whole economy, it is necessary to trace out the indirect effects on all other economic sectors in addition to the direct impact. To accomplish this, it is necessary to know how the various economic sectors relate to each other. One method that does this is input-output (I/O) analysis.

In I/O analysis, all economic activity is categorized into either endogenous or exogenous sectors. Firms within a given endogenous sector produce a set of similar goods and services for sale to other endogenous sectors or to exogenous or final demand sectors such as export and household consumption. The flow table of an I/O model describes the demand and supply relationships of an economy in equilibrium by showing final demand for goods and services and the interindustry transactions required to satisfy the demand. Coefficients which measure the direct and indirect effects of changes in output in each sector resulting from a $1 change in final demand for a given processing sector are derived from the flow tables. I/O models also permit calculations of the impact on regional output, income and employment caused by changes in final demand for a given sector.

In this study, a 43-sector open, static I/O model was used to assess the impact of erosion and flooding on the northern Ohio regional economy from Labor Day 1972 to Labor Day 1976 (Hushak, et al, 1984). The study region covered by the model is shown in

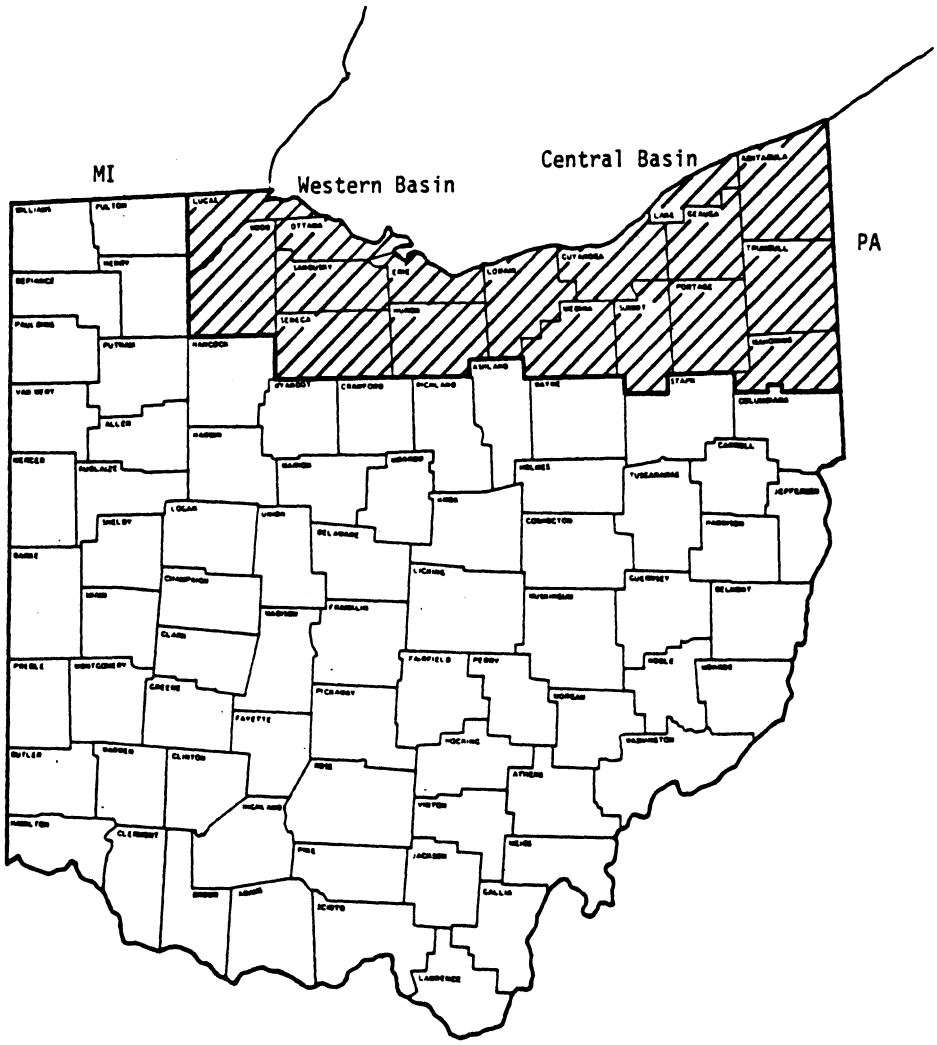
Figure 5 and includes not only the eight counties which border the Lake, but nine others in northern Ohio that are directly affected by economic activities relating to Lake Erie.

The usual application of an I/O model allows one to trace the impact of expenditures made by a particular sector on the rest of the economy since spending by that sector generates new output, income and employment under the assumption of unemployed resources in the region. In this report, however, we use the I/O model to estimate the quantity of regional output, income and employment resources diverted from the usual production of goods and services to the restoration, replacement or protection of private property because of real or anticipated storm-related damages. Under the assumption that there is full employment of all resources in the region, resources which are used to replace or restore property or to invest in shore protection must be obtained from other sectors of the economy.

## Estimates of Total Impact

Ideally, to determine the impact of storm-related floods and erosion on the northern Ohio regional economy, the sectors from which purchases were made to restore, replace and/or protect private property should be identified. However, because detailed information was not available, the descriptive data in Tables 5 and 8 were used to allocate the purchases to the appropriate sectors.

Figure 5. Study Region Covered by the I/O Model.



Although a number of sectors were probably affected, it is likely that the construction sector was most affected since the largest share of the damage and protection costs occurred in the "structures and contents," "grounds and improvements," and "protective structures" categories. Listed in Table 9 are some of the other possible sectors affected, based upon the descriptive detail found in the sample questionnaires. The average output multiplier and total income and employment effects for these sectors are similar to those of the construction sector. For these reasons, we assumed that all damage repair and protection expenditures were made in the construction sector.

Private Expenditures

Column 1 of the "Private Expenditures" section of Table 10 lists total damage and protection costs relating to floods and erosion. It was assumed that all of these expenditures were made within the study region.

Column 2 summarizes the total sales or resources required to restore or replace those destroyed resources. The estimates were calculated by multiplying Column 1 (direct spending) by the output multiplier of the construction sector (1.72). The results indicated that direct spending associated with erosion and flood-related damage required more than $111 million of regional resources during the four-year period. Similarly, the more than $38 million of protection-related expenditures required almost $66 million of resources which could have been used by other sectors to produce other goods and services.

Table 9. Impact coefficients of Sectors Potentially Affected by Erosion and Flood-Related Damages and Protection Costs, 1972-1976.

| Sector | Output Multiplier[1] | Total Income Effect[1] | Total Employment Effect[2] |
|---|---|---|---|
| Construction | 1.72 | .26 | 19.70 |
| Furniture/Fixtures | 1.94 | .44 | 24.67 |
| Misc. Machinery | 1.81 | .27 | 17.70 |
| Stone, Clay, Glass | 1.76 | .33 | 20.50 |
| Electricity, Gas, Sanitary | 1.63 | .10 | 8.75 |
| Wood/Lumber | 1.50 | .20 | 15.50 |
| Average | 1.72 | .32 | 17.80 |

[1]Dollars per dollar of final demand.

[2]Man-years per million dollars of final demand.

Source: Apraku, 1983.

Columns 3 and 4 of Table 10 show the effects of damage and protection expenditures on regional income and employment. These estimates were derived by multiplying direct spending by the total income and employment effects of the construction sector: .26 and 19.7, respectively. Income transferred from other activities to repair flood and erosion damages within the region totaled $16.8 million. Protection expenditures transferred nearly $10 million of income. Approximately 1273 man-years of employment were required for damage replacement expenditures and another 755 man-years of employment were required for protection-related expenditures. In total the $102.95 million of direct costs of damage to and protection of private property reduced other regional activity by $177 million of output, $27 million of income and 2028 man-years of employment from 1972 to 1976.

Operation Foresight projects were estimated to have prevented $22 million of damage to selected Ohio shoreline sites through 1974. If this damage estimate is accurate, total flood and erosion damages would have been 21 percent greater than they were. Resource use in terms of output, employment and income would also have increased by 21 percent. Further, resources needed to restore public facilities are unknown because we did not have data on damages to public facilities.

## Net Impact of Storms on the Regional Economy

Protection-related expenditures made through Operation Foresight amounted to $8.8 million. Since these resources were used largely to protect private property at selected sites along

Table 10. Impact of Private Expenditures on the Northern Ohio Economy, 1972-1976.

| | Direct Spending ($ mil.) | Output ($ mil.) | Income ($ mil.) | Employment (man-years) |
|---|---|---|---|---|
| Private Expenditures | | | | |
| Damage | | | | |
| Flooding | 32.22 | 55.42 | 8.38 | 634.7 |
| Erosion | 32.39 | 55.71 | 8.42 | 638.1 |
| Total | 64.61 | 111.13 | 16.80 | 1272.8 |
| Costs of Protection | | | | |
| Flooding | 16.82 | 28.93 | 4.37 | 331.4 |
| Erosion | 21.52 | 37.01 | 5.59 | 423.9 |
| Total | 8.80 | 64.94 | 9.96 | 755.3 |
| Total | 102.95 | 177.07 | 26.76 | 2028.1 |
| Public Expenditures | | | | |
| Operation Foresight | 8.80 | 8.80 | 1.23 | 78.3 |
| Net Impact of Storms on the Regional Economy[1] | 94.15 | 168.27 | 25.53 | 1949.8 |

[1]Net impact = Total Private Expenditures - Public Expenditures.

Sources: Bedford, et al. 1978.

Lake Erie, they offset private expenditures for protection as reported in the Corps of Engineers study. The $8.8 million of direct spending on protection in turn generated over $15 million of output, $2 million of income and 173 man-years of employment.

The last section of Table 10 summarizes the net impact of storms on the regional economy from 1972 to 1976. More than $94 million in regional expenditures were incurred to restore, replace and protect private property during that period, which required $168 million of output, $25.5 million of income and 1950 man-years of employment resources from the economy.

Table 11 contains information on the impact of federal aid spent for restoration, replacement and protection of public property on regional output, income and employment. Federal aid represents new resources to the region. Assuming that the grants were given in cash, only the secondary or indirect effects on output, income and employment would divert resources from the usual production of goods and services. Therefore, the $2.9 million of federal aid granted to disaster counties which generated nearly $5 million of output required $2 million ($4.99-$2.90 million) of regional resources. Diversions of income and employment resources also occurred but they were insignificant compared to those resulting from private damage and protection-related expenses.

Table 11. Impact of Public Expenditures on the Northern Ohio Economy, 1972-1976.

| Direct Spending | Output | Income ($ mil.) | Employment ($ mil.) | ($ mil.) | (man-years) |
|---|---|---|---|---|---|
| Disaster Relief | | | | | |
| | Nov. 1972 Storm | .62 | 1.07 | .16 | 12.21 |
| | Mar. 1973 Storm | 1.42 | 2.44 | .37 | 27.97 |
| | Apr. 1974 Storm | .86 | 1.48 | .22 | 16.94 |
| | Total | 2.90 | 4.99 | .75 | 57.12 |

Source: Deborah Patchen, Personal Communication, 1984.

Annual and Per Storm Estimates of Impact on Northern Ohio

In the previous section, we estimated the economic impacts of the three storms during the four year period, 1972-76. For policy purposes, however, expected annual costs are more useful. In this section, we converted the four year impacts to per year and per storm bases, and then generated an annual expected impact of storms estimate.

Average annual private damage and protection costs for the four year period were $25.7 million which required $44.3 million of output, $6.7 million of income and 507 man-years of resources annually from the study region (Table 12). On a per-storm basis, direct spending amounted to $34.3 million which required $59 million of output, $8.9 million of income and 676 man-years of employment from the regional economy.

Estimates of Expected Annual Resource Diversion Due to Storms

Historic data indicate that since 1861, there have been 12 severe northeast storms occurring when Lake Erie water levels were above their long-term average (including the three covered in this report) and three storms occurring when the levels were below average (Figure 2). Since 1861, Lake Erie water levels have been above average half of the time. Therefore, in any future year when Lake Erie levels are above average, the probability that a severe storm will occur is 12/58 or 21 percent. During a future year when the Lake level falls below its long-term average, the probability of a severe storm occurring is 3/58 or five percent.

To estimate the expected annual impact in terms of output, income and employment on northern Ohio due to storm-related damage and costs of protection, the per storm estimates from Table 12 are multiplied by the respective above and below-average storm probabilities. The results, summarized in Table 12, indicate that in high water years, the annual expected storm-related costs to the region are $7.2 million which utilizes $12.4 million of output, $1.9 million of income and 142 man-years of employment. In low water years, the annual expected storm-related costs are $1.7 million which direct $3 million of output, $450 thousand of income and 34 man-years of employment from the production of regular goods and services of the region.

## Conclusions and Implications

### Summary

In November 1972, April 1973 and March 1974, Ohio's Lake Erie shoreline counties experienced severe storms that caused extensive erosion and flood damage to both public and private property. As a result of those storms, the U.S. Army Corps of Engineers conducted surveys of private property owners along the Lake to gather information about the amount and types of damages sustained by the region and costs associated with shoreline protection from Labor Day 1972 to Labor Day 1976.

The study results showed that most of the $64 million of flood and erosion damages occurred to residential properties in the four western Ohio counties bordering Lake Erie.

Table 12. Annual, Per Storm and Expected Annual Impact of Private Expenditures on the Northern Ohio Economy, 1972-1976.

| | Direct Spending ($ mil.) | Output ($ mil.) | Income ($ mil.) | Employment (man-years) |
|---|---|---|---|---|
| Per Year | | | | |
| Damage | 16.15 | 27.78 | 4.29 | 318.20 |
| Cost of Protection | 9.59 | 16.49 | 2.49 | 188.83 |
| Total | 25.74 | 44.27 | 6.69 | 507.03 |
| Per Storm | | | | |
| Damage | 21.54 | 37.04 | 5.60 | 424.27 |
| Cost of Protection | 12.78 | 21.98 | 3.32 | 251.77 |
| Total | 34.32 | 59.02 | 8.92 | 676.04 |
| Expected Annual | | | | |
| High Water Year[1] | | | | |
| Damage | 4.52 | 7.78 | 1.18 | 89.10 |
| Cost of Protection | 2.68 | 4.62 | .70 | 52.87 |
| Total | 7.20 | 12.40 | 1.88 | 141.97 |
| Low Water Year[2] | | | | |
| Damage | 1.08 | 1.85 | .28 | 21.21 |
| Cost of Protection | .64 | 1.10 | .17 | 12.59 |
| Total | 1.72 | 2.95 | .45 | 33.80 |

[1]Calculated by multiplying per storm estimates by 21 percent, the probability of a storm occurring in a high water year.

[2]Calculated by multiplying per storm estimates by five percent, the probability of a storm occurring in a low water year.

Source: Calculated from Table 10.

Most of the $38 million of flood and erosion protection costs were also spent by owners of residential properties in the western basin counties although expenditures on erosion protection were more evenly spread among the eight shoreline counties. Federal disaster grants to northern Ohio counties over the study period amounted to $2.9 million and the value of Operation Foresight projects completed in Ohio exceeded $8.8 million.

To determine the impact on the northern Ohio regional economy of erosion and flood-related damages and protection costs, the output multiplier and total income and employment effects of the construction sector were used. The results showed that the $103 million of storm damage and related shore protection costs required $177 million of output, $27 million of income and 2028 man-years of employment resources from the region over the four-year study period which was offset somewhat by the influx of federal funds in the form of Operation Foresight resources totaling over $8.8 million. The net impact on northern Ohio of the more than $94 million of flood and erosion-related expenditures was a diversion of $168 million of output, $25.5 million of output and 1950 man-years of employment from production of the usual set of goods and services. Using historical data, the expected annual cost of storm damage and protection in northern Ohio is $7.2 million in a high water year and $1.72 million in a low water year. The output, income and employment resources required to satisfy these costs would be $12.4 million,

$1.9 million and 142 man-years, respectively, in a high water year and $3 million, $450 thousand and 34 man-years, respectively, in a low water year.

Study Limitations

Because certain information was inaccessible, it was impossible to identify the sectors in northern Ohio from which private property owners made purchases for the restoration and protection of their properties. The data limitation also prohibited an accurate determination of the share of public and private expenditures that went to each of those sectors. Although assigning all expenditures made during the four year period to the construction sector is reasonable, at best, it provides only a rough estimate of the impact that floods and erosion had on the northern Ohio regional economy from 1972 to 1976.

The magnitude of public funds spent within the region over the study period is almost certainly understated in this report since federal disasters are declared only when "local and state resources have been exhausted." The report also does not include estimates of public funding for the routine repair and/or protection of state parks and beaches, highways and other public properties along the shore. Although state and county officials were contacted and asked for information concerning such expenditures, they could not provide it because the data did not exist or because the figures were not readily accessible. Also, Corps of Engineers personnel contacted in the course of assembling background data for this report indicated that Section 14 or

"small projects" funds were spent on certain local emergency shore protection projects along Ohio's Lake Erie shoreline during the study period (exclusive of Operation Foresight projects). However, those data were not available either.

This report focused on flood and erosion damages and protective measures attributable to the three major storms of the study period. Although all flood damage and protection costs can reasonably be attributed to storms, erosion is a continual process on the Lake which is worsened under high water conditions and which can become severe during storms. To the extent that erosion damages and protection costs were made to eliminate or reduce that baseline type of erosion, estimates of annual and per-storm expenditures are somewhat high.

Although questionnaires distributed by the Corps of Engineers solicited information from respondents about physical losses of their beach and bluff property through erosion, an economic value was not assigned to these losses. Therefore, the final damage estimates may be understated, especially in the central basin counties where reported losses of beach area and bluff volumes were nearly twice those of western basin counties. (Data on beach and bluff loss from the tables accompanying the Corps of Engineers report were provided by study respondents. These estimates were not extrapolated to the whole population so it was impossible to ascertain the actual magnitude of beach and bluff losses).

The three storms of this study period were atypical in that they occurred so closely in time, yet there is no evidence that these storms were any more or less severe than those of the past. To the extent that they may have been more severe than normal, per-storm estimates of future damage in a high water year (Table 12) are overstated.

Implications

Prior to the storms discussed in this report, the last one of comparable magnitude and destructiveness occurred in 1952. Since that time, Ohio's Lake Erie coastline has undergone unprecedented growth and development. In fact today, Lake Erie's Ohio shoreline is the most urbanized of the Great Lakes' shorelines, an important reason why recenterosion and flooding have been so costly to the region ($GLBF_d$, 1976). The Great Lakes Basin Framework Study in 1976 projected that growth and development along the shore would continue and that urban areas would gain primarily at the expense of cropland (which is largely found in the western basin, the area suffering the most damage from recent storms and where construction of the Lake-based recreation facilities such as marinas has grown fastest). Federal aid granted to selected northern Ohio communities in the aftermath of the storms came only after local resources were exhausted and it was designated for replacement or restoration of public property. Since shore development is expected to continue, placing increas-

ingly valuable property at risk of storm damage, it seems imperative that local resources be mobilized to build permanent shore protection structures.

The estimates of expected annual diversion of output resources from the regional economy for storm-related restoration and protection of property ($6.5 million in high water years and $1.5 million in low water year) serves as a benchmark for investment in shore protection. Since the early 1970s Lake Erie water levels have remained above the long-term average and, since there is no indication that water levels will decline in the near future, it is reasonable to conclude that the $6.5 million estimate is the better investment benchmark figure.

The issue of who should bear the costs of protecting the Lake Erie shoreline is critical. Funds to protect state and federally-owned properties may be generated through general sales or income taxes. Matching funds for large local projects may be offered to communities located in more susceptible areas. At the county, city or township level, an assessment based on frontage may be collected in order to generate funds to build shore protection structures.

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